# Chapter 14
# River Ice Problem Identification

## 14-1. Surveys Needed

To fully understand the ice processes involved and their effects on winter navigation, the entire river system needs to be fully defined. A general survey of the river system should be made, defining its hydraulic characteristics under open-water conditions, as well as how these characteristics change in times of ice. This survey should indicate how extensive the ice problems are and where they are most concentrated. Areas of ice generation, growth, and deposition, as well as ice-cover initiation points, should be identified. All tributaries must be considered to determine their ice inputs during freezeup, throughout the winter, and during breakup periods. Existing hydraulic structures, such as navigation dams, locks, or hydropower installations, should be examined to see how they influence the river system under present operating procedures. Can these structures control flow? Do they retard velocities, thereby causing ice deposition? Which dams pass ice and how do they pass ice? What influence does ice passed through a dam have on ice problems downstream? What facilities exist for ice passage at locks and dams? Some dams may only be able to pass ice during high flows, while other structures use the auxiliary lock chamber for routinely passing ice. Questionnaire-type surveys can be employed to gain the information outlined above (Haynes et al. 1993, Zufelt and Calkins 1985). These surveys should poll river users as well as the operators of any structures. These and subsequent interviews with specific users will yield information about things such as areas of ice cover, areas of ice generation, ice thicknesses, types of ice, and restrictions to flow and ice passage. Ice problem locations can be identified, as well as other areas of concern, i.e., high traffic areas, temporary fleeting areas, etc.

## 14-2. Hydrology and Hydraulic Studies

Records should be examined to determine if there have been any previous hydrological or hydraulic studies of portions of the river system. Flood insurance studies, working numerical hydraulic models, navigation models, and backwater studies may offer data on flow velocities, discharges, stages, operational procedures, etc. Some existing mathematical models (such as HEC-2) have been adapted to incorporate an ice cover into the system. Rainfall and snowmelt runoff models for tributaries may give insight into when and with what magnitude the ice cover will break up. Past physical model studies of navigation structures or hydropower installations can give insight into ice movement, accumulation, and passage, as well as ice effects on tows. Ice retention in tributaries and non-navigable main stem reaches must be studied. Existing and planned physical models can incorporate ice studies into their modeling sequence. In conducting any hydraulic or hydrological studies, it is important to obtain as much information on the ice characteristics of the river system as possible. Winter field observations are an invaluable source of information on ice thicknesses and areas of ice cover. Operational logs of lock and dam facilities usually contain information on weather and waterway conditions. Hydropower and other power plants, as well as water supply or treatment plants, often keep records of water and air temperatures, along with ice conditions at their intake or outfall structures. Towing companies sometimes keep records of ice conditions, especially when they affect shipping schedules. River users and structure operators generally have a good knowledge of average winter ice conditions and these people should be interviewed.

## 14-3. Identification of Ice Problems

Ice problems should be identified by type, location, and severity. On-site observations of the problem areas are also useful. A survey questionnaire to poll river users and structure operators is quite valuable. A sample questionnaire is shown in Figure 14-1.

1. Location: River ________________
   Mile ________________

2. Hydraulic structure: No ______ Yes ______________
   Name ____________

3. Problem area: Bend ________________________
   Island(s) ______________________
   Spillway Gates _________________
   Lock Gates and/or Approaches ______

4. Description of problem: (use reverse side if necessary)
   ________________________________________
   ________________________________________
   ________________________________________

5. Documentation available: Reports* ______________
   Memos* ______________
   Individuals ____________
   (*copies appreciated if available)

6. Have there been any attempts to alleviate the problem?
   No _____ Yes ______
   If yes, Re-design ________________________
   Operational changes ___________________
   Reports _______________________________

7. How does this problem rank with other ice problems in your jurisdiction in its impact on the operation of the structure/river system?
   High _______________________________
   Medium _____________________________
   Low ________________________________

8. Identify any structures that have been specifically designed, modified, or retrofitted to alleviate this ice problem:
   Site    Point of Contact    Address & Telephone Number

**Figure 14-1. Questionnaire for collecting information on ice problems affecting navigation projects and navigational activities**

*a. Information sources.* Aerial photos and video coverage of the river system during winter can provide data on problem type and location, although problem severity is best estimated by those with firsthand knowledge of the area. Lockmasters, towboat operators, and homeowners adjacent to the area in question are an excellent source of data and should be polled or interviewed as necessary. Operations personnel are usually well informed of problem areas, including emergency conditions.

*b. Problem categories.* There are two general problem categories: those occurring at or near navigation structures, and those occurring in the river pools between navigation structures. Navigation dams may experience limited ability to pass ice moving downstream because of gate-setting limitations. Spillway gates may ice up because of leaking seals or normal operations, resulting in restrictions in movement, overstressing of structural components, or even inoperability. Lock facilities may experience ice accumulations in the upper and lower approaches or behind miter gates, slowing operations significantly. Ice may adhere to the lock miter gates, lock walls, line hooks, vertical checkpins, or floating mooring bitts, resulting in increased winter maintenance. Problems generally associated with areas away from navigation structures include severe ice accumulations or jams near islands and bends, tributary ice inflows, and problems encountered near docks and fleeting areas. Following are detailed descriptions of typical ice problems that have been reported in the past. This list, however, is not all-inclusive.

## 14-4. Ice Problems Around Navigation Projects

*a. Ice in upper lock approach*. Broken ice, carried downstream by the river current and wind, or pushed ahead of tows, often accumulates in the upper lock approach, causing delays (Figure 14-2). Separate ice lockages often must precede the locking of downbound tows, and flushing ice during these ice lockages is difficult. Occasionally, a tow must back out of the lock after entry because the ice doesn't compact in the chamber as much as expected, preventing the tow from fully entering the lock chamber and thus causing further delays. Upbound tows may have to limit their size to be assured of enough power to push through the accumulations of ice. Tow haulage units usually have too little power to pull the first cuts of double lockages out of the chamber against heavy accumulations of ice. So, double trips or smaller tows are called for. During periods of low traffic, ice accumulations sometimes freeze in place, causing further delays and difficulty in operating the upper gates.

**Figure 14-2. Ice accumulation in the upper lock approach area**

*b. Lock miter gates*. Ice accumulations in the upper lock approach can cause pieces of ice to become wedged between the miter gates and the wall recesses (Figure 14-3). Ice pushed into the lock chamber ahead of downbound tows causes the same difficulties for the lower gates. The gates must be fanned or the ice pieces prodded with pike poles to make them move out of the way. Sometimes, compressed air lances or steam jets are used to disperse the trapped ice.

*c. Ice buildup on lock walls and miter gates*. During extremely cold weather, and with fluctuating water levels in lock chambers, ice will build up on the lock walls and miter gates, forming a collar (Figure 14-4). This collar is thickest at the upper pool level. Enough ice can build up on the walls to keep the gates from being fully opened, thus limiting the width of tows and leaving the gates exposed to

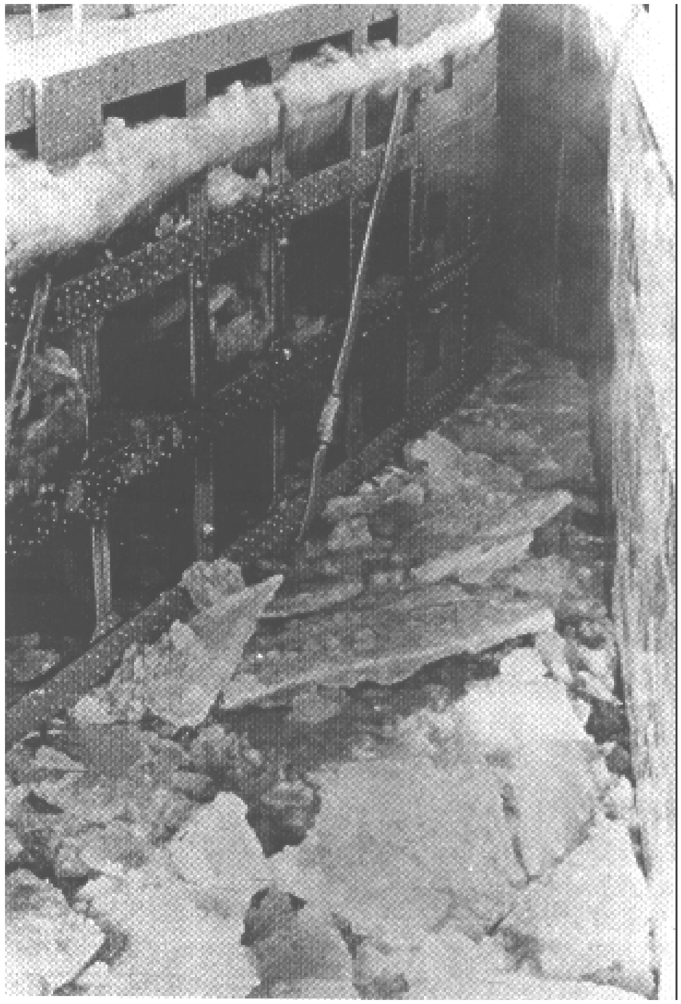

**Figure 14-3. Broken ice accumulation between the lower miter gate and the gate recess wall, which hinders full recessing of the gate**

damage. Even where the buildup is minimized or controlled in the gate recesses, ice on the chamber walls can be thick enough to restrict tow widths. Most of the inland waterways that have barge traffic can place width restrictions on the lock chambers. This is not desirable, but at least it allows navigation to continue with narrower tows. (On river systems such as the St. Marys or the St. Lawrence, however, the usable width of the locks is critically important, because the vessel widths can't be reduced.)

*d. Floating mooring bitts*. Ice pieces may jam between the floating mooring bitts and the lock wall, rendering the bitts inoperative. Ice layers may build up on the wheels, track, or flotation tank of a bitt (Figure 14-5), causing the bitt to freeze in place; the bitt can then dangerously and unexpectedly jump upward from its submerged position. Usually, bitts must be tied off at the top of the lock wall and remain unavailable for winter use.

*e. Vertical checkpins or line hooks.* The vertical checkpins or line hooks in the lock walls may accumulate layers of ice because of fluctuating water levels. This causes difficulties when check lines slip and jump off the pins or hooks.

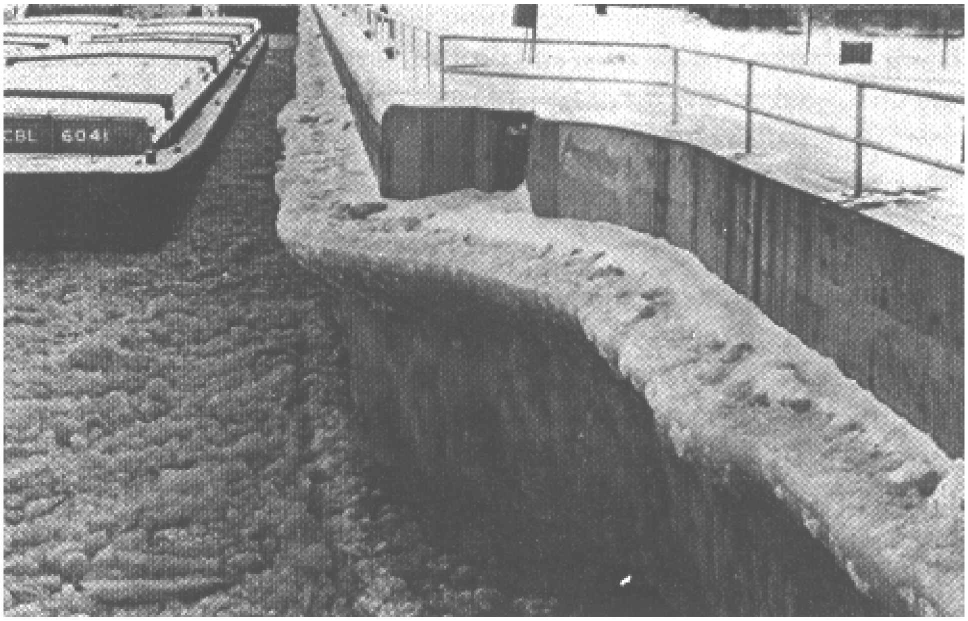


**Figure 14-4. Ice collar formation on the gate recess and chamber walls, restricting the full opening of the miter gates and limiting the usable width of the lock**

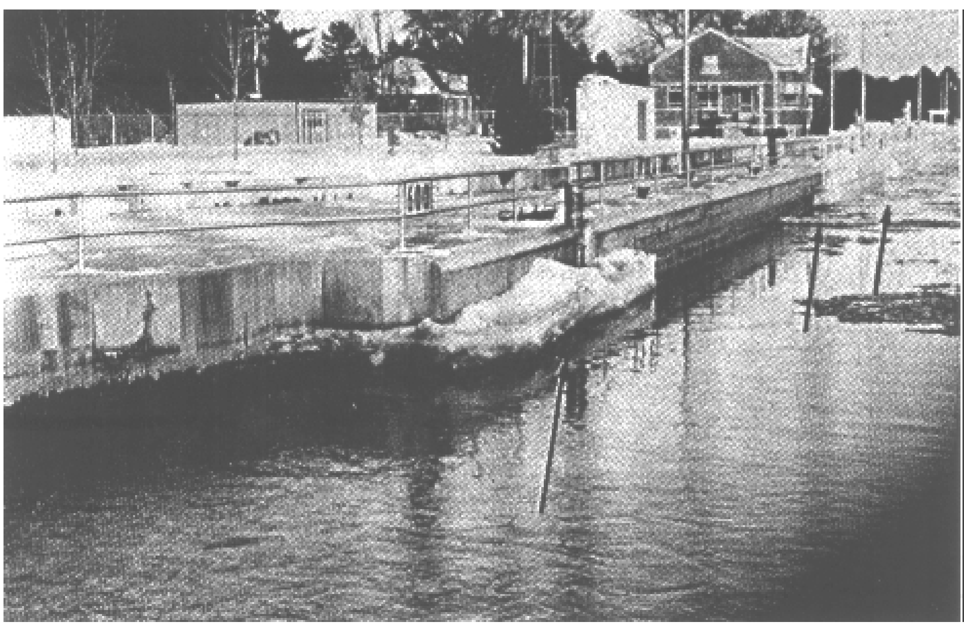

**Figure 14-5. Ice interference with floating mooring bitts (arrows) in a lock chamber wall**

*f. Ice in lower lock approach.* Ice may accumulate downstream of a lock because of upstream wind, or an island, bend, or other constriction. Ice passing through the lock or over the spillway adds to this accumulation. The continual buildup of ice may block the entrance to the lock for upbound tows.

*g. Dam spillway gates.* Broken ice carried downstream usually accumulates at the dam (Figure 14-6). During periods of low flow, normal gate openings are small and will not pass this ice. Low tailwater presents a problem of excessive scour if gates are raised high enough to pass the ice. In colder weather, these accumulations will freeze in place, making it necessary to break up the ice to start it or keep it moving (usually done by towboats). Some lock and dam facilities have been equipped with submergible tainter gates specifically designed for passing ice and drift. At a few installations, the gates are rarely used in the submerged settings, owing to excessive vibrations that could cause damage to the gate and supporting structure of the dam. Some of these submergible gates have been retrofitted to prevent them from being used in the submerged position. Other lock and dam facilities report no problems with operating these gates in the submerged position. A feature of all submergible gates is that they leak more than nonsubmergible gates. In winter, freezing of this leakage adds to the problems described in the following two paragraphs. Three installations on the Monongahela River are equipped with split-leaf (movable crest) tainter gates, designed for passing ice and debris. The gates seem to work well, but during periods of low flow, towboat assistance is required to break up the ice behind the dam and start it moving. Lock and Dam No. 16 on the Mississippi has reported that an emergency bulkhead placed in the entrance to a roller gate bay passes ice well.

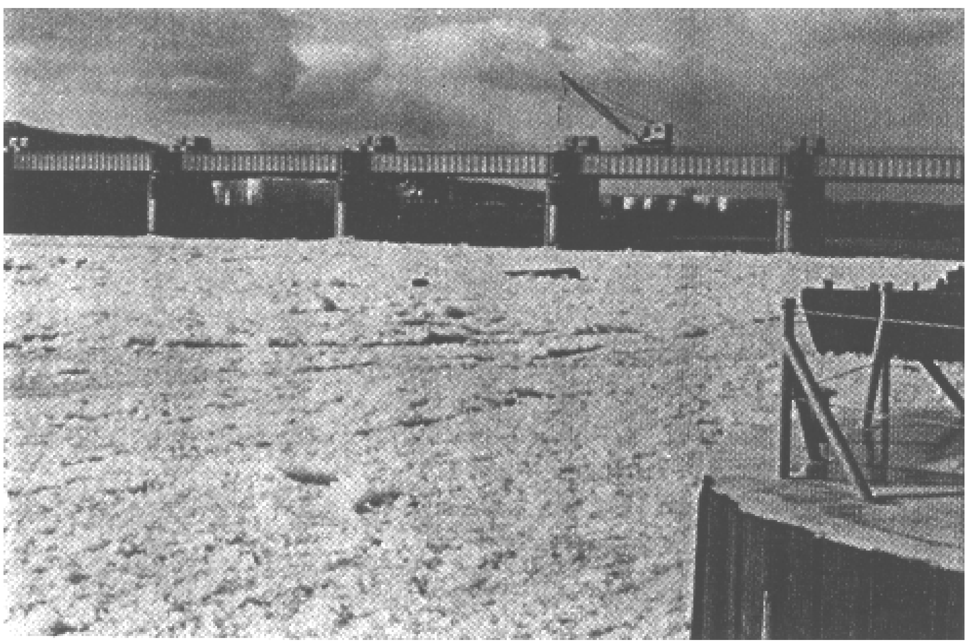

**Figure 14-6. Ice accumulation upstream of the gates of a navigation dam**

*h. Spray icing of spillway gates.* Spray from the operation of spillway gates can cause ice to form on the pier walls or under the arms of tainter gates (Figure 14-7). This may cause jamming or stop the gates from fully closing. In some cases, the weight of ice formed on the gate structure is so great that the operating machinery cannot raise the gate.

*i. Tainter gate seals.* The side and bottom seals of tainter spillway gates may leak, causing spray. This spray results in ice buildup on the pier walls or the gates themselves, causing operational difficulty

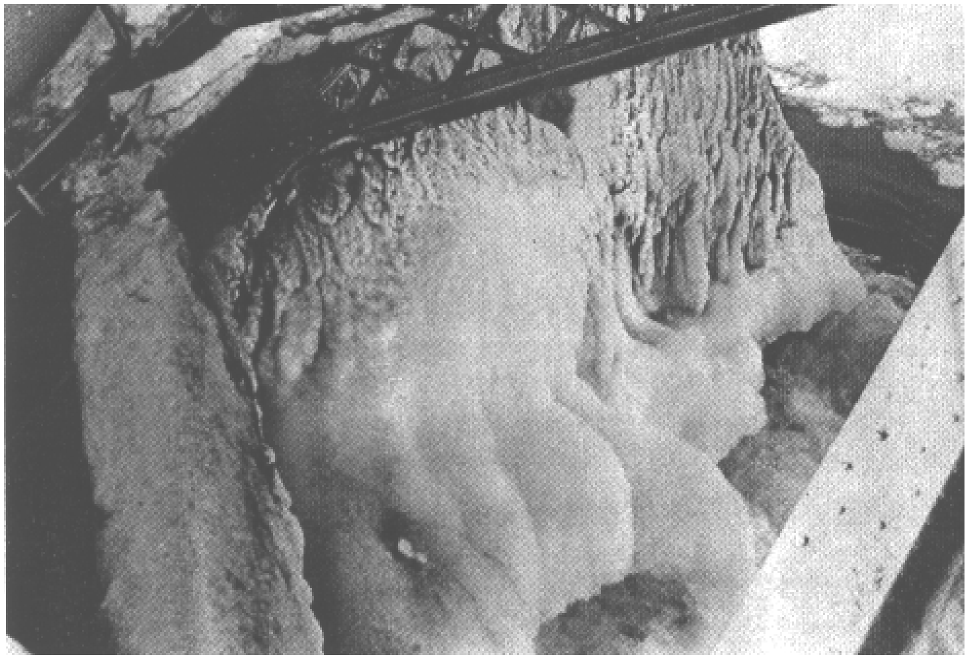

**Figure 14-7. Tainter gate structure and gate pier wall with icing that has accumulated through spray and splashing in the course of winter operation**

(Figure 14-8). It is possible for this ice to bridge across from the pier to the gate, rendering the gate seal heaters ineffective. During severe cold, the gates must be moved frequently or they will freeze in place. Attempts to operate gates when frozen in place can result in damage to the operating machinery, hoisting mechanisms, and chains or cables.

*j. Ice formation on intake trash racks.* Broken ice and frazil ice can accumulate on trash racks, causing a reduction in flow. This results in loss of water supply and possible shutdown if flows are substantially blocked. In the case of hydropower intakes, power production may be interrupted.

## 14-5. Ice Problems Occurring Between Navigation Projects

The channels around islands, bends, and other constrictions tend to accumulate thick deposits of ice (Figure 14-9). During periods of significant ice, these accumulations may form jams, which can cause scouring and eroding of bed and banks. Navigation can be interrupted or delayed and structural damage is possible, especially during breakup of the jam. Minor jams may raise the water level upstream, while major jams can cause severe flooding. Tows must limit their size in some problem areas.

*a. River bends.* River bends are often the cause of ice accumulation. The nonuniformity of depth and velocity over a bend cross section, coupled with secondary flow circulation, results in a nonuniform ice cover. Under open-water conditions, multiple cells of secondary currents are set up that, in general, push surface water toward the outside of bends and bed material toward the inside of bends (Figure 14-10). If these same circulations exist under ice conditions, one would expect thick accumulations on the outside of bends, while the relatively tranquil flow on the inside of the bend would allow shore ice to form easily, reducing the open surface width. Limited laboratory experiments (with a fixed bed) have shown that these secondary currents may be modified by the presence of an ice cover, further compounding the nonuniformity of the ice cover. In addition to this nonuniformity, vessels often have

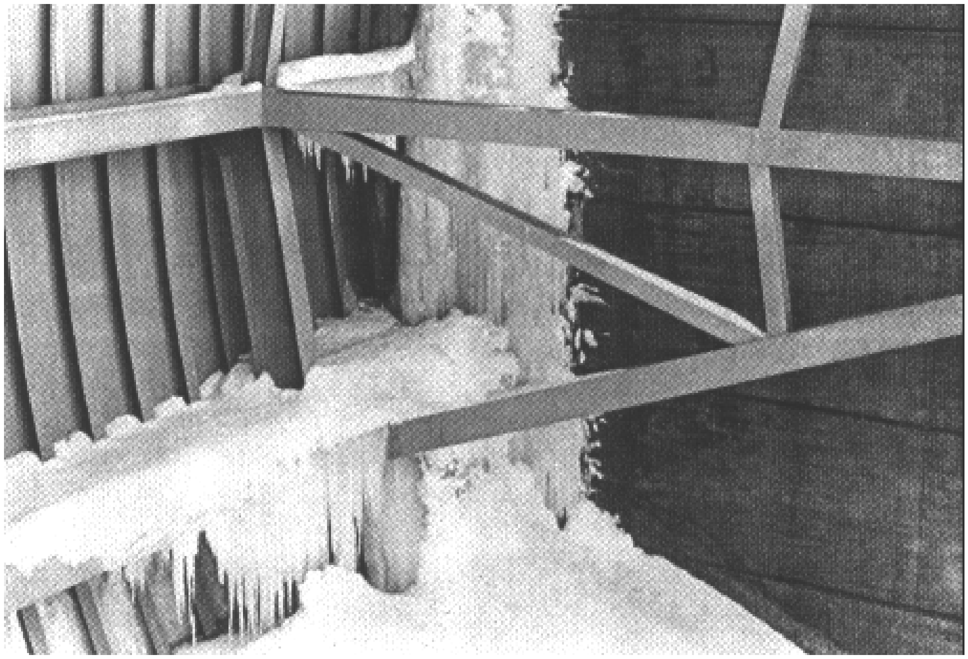

Figure 14-8. Tainter gate frozen in place by ice formed by leakage past the gate's side seals

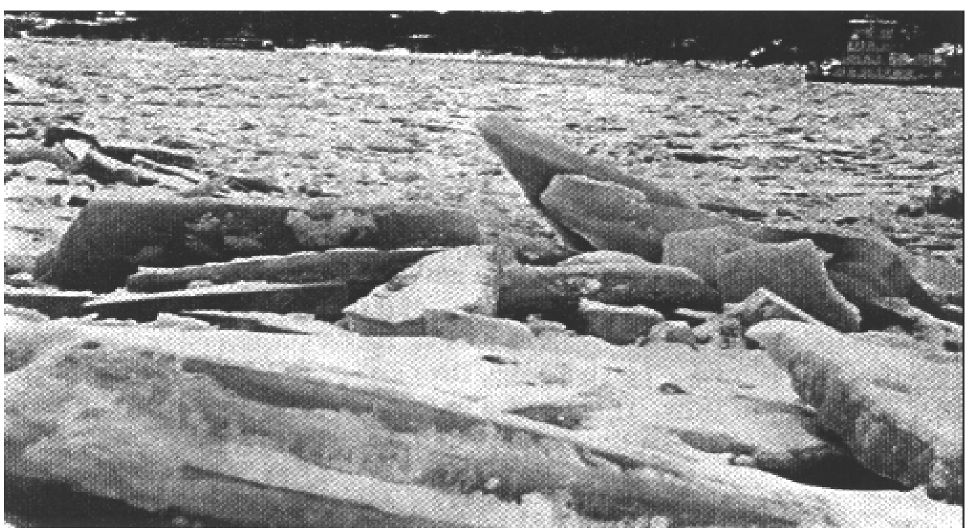

Figure 14-9. Heavy accumulations of ice floes and brash ice

trouble tracking around bends under ice conditions, particularly severe bends as on the upper Monongahela River. Figure 14-11 shows a vessel track around a severe bend. Note the wide, irregular appearance of the track caused by transiting problems. Experience in the Pittsburgh District indicates that river bends having 110 degrees or more of curvature will cause transiting difficulties when ice is present.

*b. Reduced open width of river surface*. Laboratory experiments with plastic "ice" have shown that there is a relationship between the characteristic size of ice floes and the open width of a channel for the occurrence of arching and channel blockage. Once blockage has taken place, an accumulation of surface

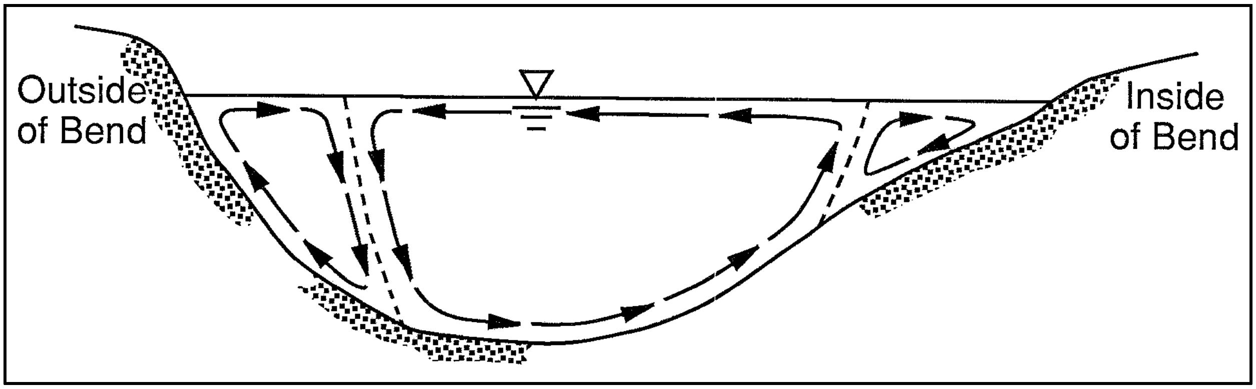


**Figure 14-10. Transverse velocities forming secondary circulation cells in river bends**

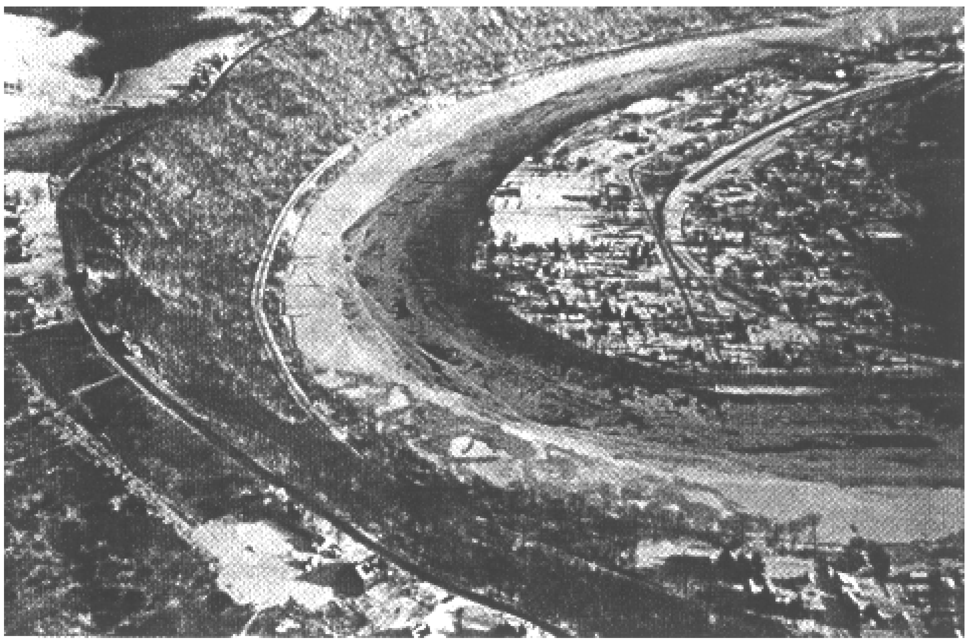

**Figure 14-11. Broken, irregular vessel track around a sharp river bend, indicating difficulties in navigating through the ice**

floes may progress upstream. One mechanism that accelerates the blockage process is the growth of shore ice, which reduces the open width of the river surface. The shore spans of bridges often freeze over quickly during periods of low flow, and this width reduction may be enough to cause blockage when ice discharge in the river is high. Figure 14-12 shows the Allegheny River at Pittsburgh, Pennsylvania, where the open surface width has been reduced significantly by the freeze-over of the shore spans of several bridges. Islands may also cause a reduction in open surface width. Typically, one channel around an island carries the major portion of flow while the other freezes over. Again, this surface-width reduction may be enough to initiate blockage. Figure 14-13 shows an island with one of the channels frozen over.

*c. Tributaries*. During breakup, tributaries may discharge large quantities of ice into the main river. If the main river is still frozen or partially ice-covered, an accumulation may result. On a large scale, this is what happens when the Monongahela River breaks up, discharging ice into the Ohio River. Typically, only the larger tributaries are significant and the duration of this type of problem is small. Very steep

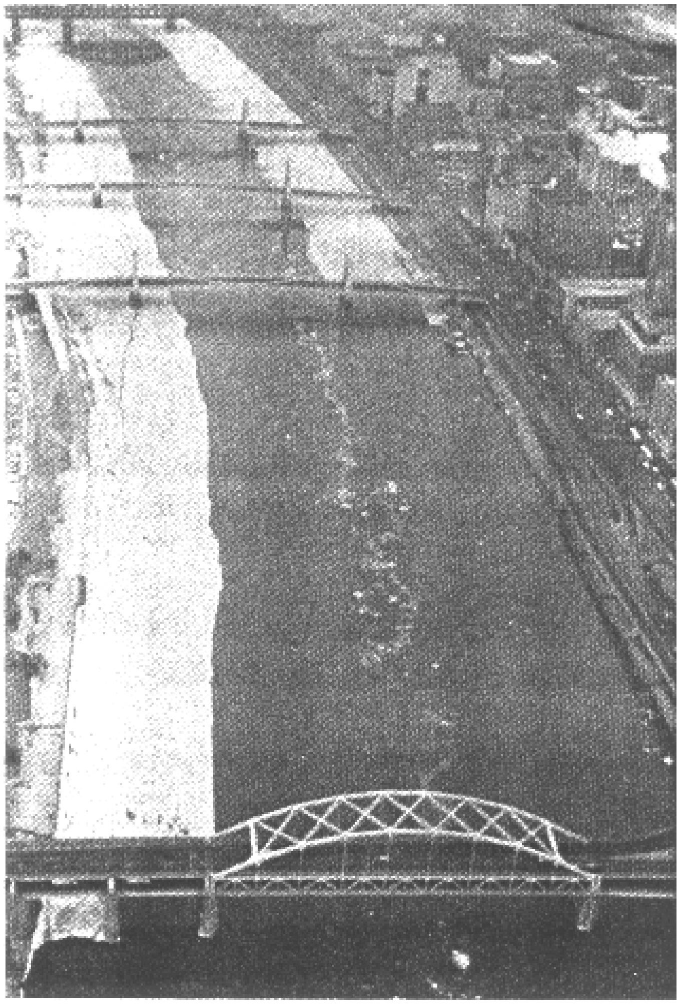

**Figure 14-12. Shore ice formation, with bridge piers providing added stability to the shore ice**

tributaries may remain open all winter long, generating large quantities of frazil ice. The upper reaches of the Allegheny River (above Lock and Dam No. 9) supply frazil to downstream areas through the winter. Tributaries, whether large or small, may also have fans or bars extending into the main river. These shallower areas tend to freeze over quickly, extending shore ice into the river and reducing the open surface width. A special case exists on the Illinois Waterway in the vicinity of Marseilles Lock and Dam. The river is split by a long island, with the dam at the upstream end of one channel (the north channel) and the lock at the downstream end of the other (the south channel). The north channel is fairly steep and generates frazil ice all winter long. The south or navigation channel is flat and generally freezes as a lake. A short distance downstream of the lock, the two channels rejoin with a flat slope. The frazil moving down the steep north channel suddenly loses velocity and tends to accumulate downstream of the junction. Accumulations in this area can reach thicknesses of 1.8 meters (6 feet) and lengths of 0.8 kilometer (1/2 mile). It is not unusual for towboats to spend 10 to 18 hours to navigate through this section.

*d. Fleeting and mooring areas*. Under midwinter conditions, there is often a narrow shipping track that remains open following the channel line in an otherwise frozen river. This is characteristic of the

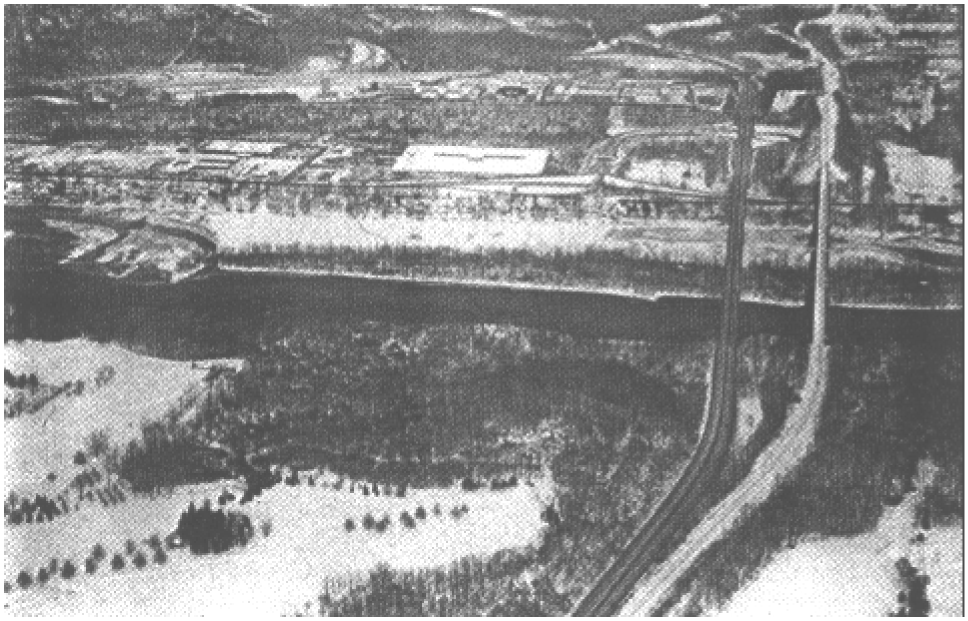

**Figure 14-13. River divided into two channels by an island; the main channel is open while the secondary or back channel is ice covered**

upper Monongahela River. Tows travel in these established tracks, leaving them only to move to mooring cells, fleeting areas, or docks. If care is not taken to move to these areas by additional established tracks, large ice pieces can be broken away from the cover and become lodged in the main shipping track. Figure 14-14 shows a fleeting area near shore and an established navigation track following the shipping channel.

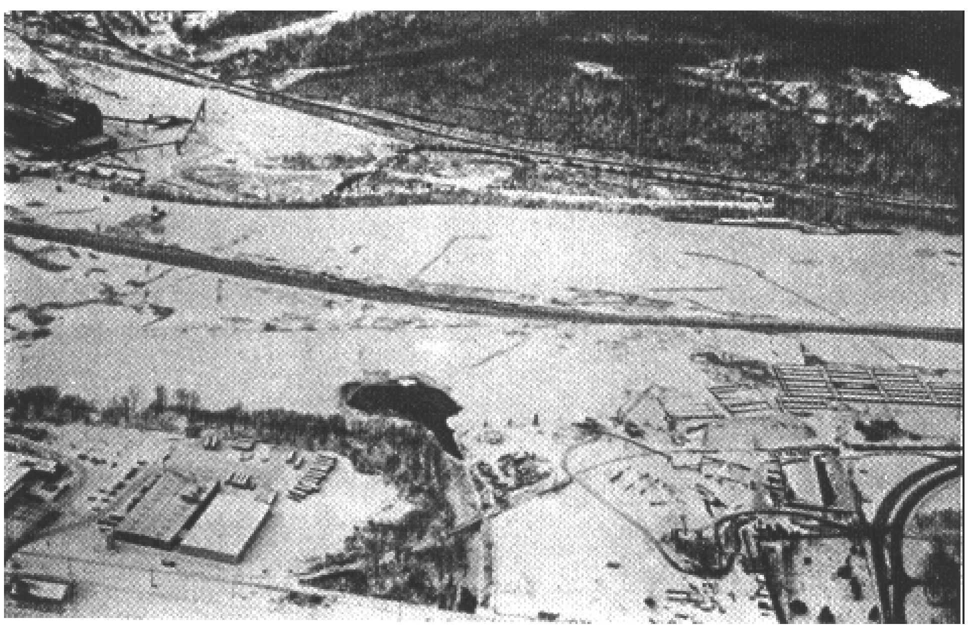

**Figure 14-14. Navigation track in the middle of the channel, with a fleeting area at the near bank; traffic using the fleeting area can break free large floes that can move out to block the track**

## 14-6. References

*a. Required publications.*
None.

*b. Related publications.*

**Haynes et al. 1993**
Haynes, F.D., R. Haehnel, and L. Zabilansky. 1993. *Icing Problems at Corps Projects*, Technical Report REMR-HY-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

**Zufelt and Calkins 1985**
Zufelt, J., and D. Calkins. 1985. *Survey of Ice Problem Areas in Navigable Waterways*, Special Report 85-2, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.